R E P O R T R E S U M E S

ED 003 380 24

AN EDUCATIONAL THEORY MODEL--(SIGGS), AN INTEGRATION OF SET THEORY, INFORMATION THEORY, AND GRAPH THEORY WITH GENERAL SYSTEMS THEORY.

BY- MACCIA, ELIZABETH S. AND OTHERS
OHIO STATE UNIV., COLUMBUS, BUR.EDUC.RES.AND SER.

REPORT NUMBER CRP-E-022 PUB DATE 66
REPORT NUMBER PAPER-65-187
EDRS PRICE MF-$0.09 HC-$1.40 35P.

DESCRIPTORS- MODELS, *THEORIES, MATHEMATICAL MODELS, *SET THEORY, *INFORMATION THEORY, *EDUCATIONAL THEORIES, COLUMBUS, OHIO

AN ANNOTATED BIBLIOGRAPHY OF 20 ITEMS AND A DISCUSSION OF ITS SIGNIFICANCE WAS PRESENTED TO DESCRIBE CURRENT UTILIZATION OF SUBJECT THEORIES IN THE CONSTRUCTION OF AN EDUCATIONAL THEORY. ALSO, A THEORY MODEL WAS USED TO DEMONSTRATE CONSTRUCTION OF A SCIENTIFIC EDUCATIONAL THEORY. THE THEORY MODEL INCORPORATED SET THEORY (S), INFORMATION THEORY (I), GRAPH THEORY (G), INTO GENERAL SYSTEMS THEORY (GS), AND WAS CALLED THE "SIGGS" THEORY MODEL. THE ILLUSTRATIVE USE OF THE SIGGS THEORY MODEL INCLUDED--(1) MARKING OFF A SCHOOL AS A SYSTEM, (2) SETTING FORTH VARIABLES OF A SCHOOL AS A SYSTEM, AND (3) RELATING THESE VARIABLES THROUGH SCIENTIFIC HYPOTHESES. THE USE OF THE SIGGS THEORY IN DEVELOPING OTHER THEORY WAS DESCRIBED AS BEING RETRODUCTIVE RATHER THAN REDUCTIVE OR DEDUCTIVE. THIS PAPER IS ONE OF A SERIES OF 11 PAPERS WHICH WILL BE PUBLISHED TO DESCRIBE THE SIGGS THEORY AND THE SIGGS THEORY MODEL BEING DEVELOPED UNDER COOPERATIVE RESEARCH PROJECT E-022. (JM)

ED003380

Part of CR E-022

AN EDUCATIONAL THEORY MODEL: (SIGGS), AN INTEGRATION OF SET THEORY, INFORMATION THEORY, AND GRAPH THEORY WITH GENERAL SYSTEMS THEORY

Educational Theory Center
Occasional Paper 65-187

Elizabeth Steiner Maccia
George S. Maccia
James F. Andris
Kenneth R. Thompson

BUREAU OF EDUCATIONAL RESEARCH AND SERVICE, THE OHIO STATE UNIVERSITY

U. S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Office of Education
This document has been reproduced exactly as received from the person or organization originating it. Points of view or opinions stated do not necessarily represent official Office of Education position or policy.

Acknowledgment

This paper is part of Project E-022, and one of a series which presents the educational theory model. This research is supported under the Cooperative Research Program of the Office of Education, U. S. Department of Health, Education, and Welfare.

Introduction

In the last two papers of this series, the SIGGS Theory was presented. To state the matter differently, the terms and propositions of general systems theory into which were incorporated aspects of set theory, information theory, and graph theory were presented. The purpose of this paper is twofold: first, to describe the situation with respect to the use of the various theories of the SIGGS Theory in constructing theory of education; and secondly, to show how one can go beyond this situation by the use of the SIGGS Theory as a model to construct a theory of education which is scientific in nature. The means for achieving the first purpose will be an annotated bibliography and a discussion of its significance, while the means for the second will be a discussion of the use of the SIGGS Theory as a theory model particularly within the context of constructing a scientific theory of education. This paper, as the last of the third series of papers, will provide a transition from the first (1), second (2), and third series of papers (3) to the fourth (4) and final series of papers in this project: Cooperative Research Project E-022: Development of Educational Theory Derived from Three Educational Theory Models (5).

The Utilization Situation

General Discussion

The basis for decision whether the theories (set theory, information theory, graph theory, and general systems theory) or any combination thereof is being used to construct educational theory depends

upon what each of the theories and educational theory are taken to be. Set theory consists of propositions which characterize the properties of a collection, a class, an aggregrate, etc., the relationships between them, and the operations on them. Information theory is taken in a selective sense, and so consists of propositions characterizing representations as sets of alternatives. Graph theory is taken in the sense of digraph theory, and so consists of propositions characterizing patterns constructed from points and lines. General systems theory consists of propositions characterizing complexes of elements standing in interaction. Finally, educational theory consists of propositions characterizing the teaching-learning process in the context of the school.

Only one utilization of set theory (item 4) and one of graph theory (item 7) in the construction of theory of education could be discovered. The educational literature dealing with the sociometric analysis of classroom groups is relevant to graph theory, since a sociogram is representable by a graph. In this literature, however, the relevance is not indicated. A classic study of this type is Cook's sociometric diagrams in which he exhibits the structural changes within a classroom when attempts are made to modify its structure. (6) Studies similar to Cook's do not provide a basis for the use of graph theory in the construction of educational theory.

Both information theory and general systems theory have been utilized to a greater extent than set theory and graph theory in the construction of educational theory. Nevertheless, the actual use has not been extensive.

As a general rule, the selective aspect of information theory has been neglected. Consider this quotation from an analysis of classroom interaction:

> . . . attention will be focused mainly upon the cognitive content of communication as a vehicle for analysis . . . If "information" is used as a general descriptive term denoting the facts, concepts, . . . etc., about which communication takes place, we may make a distinction between sending and receiving [as behavior categories] . . . (7)

Consider also items 2, 15, 16, and 17 of the annotated bibliography.

In regard to the utilization of general systems theory, simply employing the term, 'system', does not necessarily involve such utilization. An example would be the theorizing about conceptual systems (8) which has led to theorizing about education. (9) Furthermore, employment of more terms from systems theory other than 'system' does not insure utilization of general systems theory in educational theorizing. An illustration among the many in the literature would be the non-mathematical model [theory] of the act of spelling. (10) Merely to put together input (sources of spelling and linguistics), throughput (channel and register), and output (spelling in action) does not involve the propositions which constitute general systems theory. Finally, systems analysis is not general systems theory, and so literature in education which concerns itself with the selection and arrangement of components in a school or school system for efficient realization of a given outcome or outcomes is not cited in the annotated bibliography. T. Greenfield, for instance, treats the selected outcome, achievement on departmental examinations of 9th grade pupils of Edmonton, in relation to the components, the pupils within the schools within the school district. (11)

There has been only one attempt to combine any of the theories within the Siggs Theory as a basis for constructing of educational theory (item 9). (12) One monograph (13), whose author appears to do so, lacks conceptual clarity. A cogent example of the confusion is the equating of general systems theory, cybernetics, and information theory. Within this same work, one also could point to questionable propositions, some of which even are contradictory. To illustrate: "Information theory views all systems as dynamic (open), yet reasonably stable (closed)." (14) Ryans' work (item 15) which uses general systems to theorize about education also does not use selective information. The definition of 'information' taken from his work substantiates this claim: "In the sense that the term "information" is employed here, it is best defined in terms of signs that have semantic and/or pragmatic referents . . ." (15).

The conclusion of this general discussion of the annotated bibliography to follow is patent: the current situation with respect to the use of set theory, information theory, graph theory, and general systems theory in education theory construction is not in a very advanced stage of development.

Annotated Bibliography

1. Abdel-Halim, Ahmed El-Mahdi, "An Intersystem Model for Curriculum Theory and Practice," Doctoral Dissertation, The Ohio State University, 1965.

A. Abdel-Halim defines the properties of a system which he will use as a basis for developing curriculum theory. Specifically, curriculum is considered as a system of which three subsystems--content, psychological processes, and instructional setting--are identified and explicated. In

his theorizing, he attempts to establish four methodological hypotheses: "1. If curriculum is to be conceived as a system, then its main features can be identified and represented in a model. 2. If curriculum is to be treated as an intersystem model, then the patterns of relationship among its subsystems can be shown. 3. If curriculum is conceived as intersystem, the role or the roles played by each subsystem can be explained in its relative autonomy, and in its mutual reaction to other subsystems. 4. If curriculum is to be handled as a system, the sources of imbalance within the system due to internal and external change can be accounted for" (pp. 21-22).

2. Gordon, Ira J., "Developments in Human Behavior," Educational Theory, Vol. 8, No. 4, 1958, pp. 259-268.

I. Gordon considers some properties of an open energy system and discusses its relevance to education. For example: "We are saying that the individual is always active, is in constant transaction with the environment, is always moving in the direction of increased complexity, and acts to order himself and his environment" (p. 262), "We have said that information is essential to the system. It takes information to maintain organization. There must be input" (p. 265), and "knowledge of growth processes leads us to the recognition that one's presently developed self-system, including, of course, one's physical organism, sets limits on what will be perceived, experienced, turned into information, and therefore "learned" "(p. 266).

3. Griffiths, Daniel, "Some Assumptions Underlying the Use of Models in Research," Educational Research: New Perspectives, ed. by J. A. Culbertson and S. P. Hencley, Danville, Illinois: The Interstate Printers and Publishers, Inc., 1963, pp. 121-140.

D. Griffiths uses general systems theory as a model for a theory of administrative performance. He defines 'a system' as a complex of elements in mutual interaction. Two kinds of systems are noted, open and closed, and seven properties of open systems are cited: inputs and outputs, steady states, self-regulation, equifinality, sub-systems, feedback, and progressive segregation. From these properties, two propositions are developed: "The steady state of an administrative performance system is maintained by a decision process in which satisfactory alternatives are selected rather than optimal alternatives" (p. 137) and "Administrative systems respond to continuously increasing stress first by a lag in response, then by an over-compensating response, and finally by a catastrophic collapse of the system" (p. 138). Evidence supporting these two propositions is presented and discussed.

4. Henderson, Kenneth B., "A Logical Model for Conceptualizing and Other Related Activities," Educational Theory, Vol. 13, No. 4, 1963, pp. 277-284.

K. Henderson uses set theory to explicate conceptualizing. He considers conceptualizing as a 4-tuple relation which includes a term, a person, a context, and a meaning. Since there is an explicit mention of the classroom, set theory could be considered as used in developing educational theory. In the use of set theory, however, there are mathematical difficulties which produce theoretical ones. For example, the sets considered are not well-defined.

5. Husek, T. R., "Message Certainty and Information Destruction: Variables in the Study of the Communication of Information," California Journal of Educational Research, Vol. 15, 1964, pp. 184-189.

"This paper describes an experiment on two variables related to the communication of information. . . . the results obtained have importance for the field of education." (p. 184) Since the experiment is obviously in the context of selective information theory, the construction of an educational theory in such a context is implied.

6. Kopstein, Felix F., "Methodological Considerations," Chapter of the ETS Report on the Pennsylvania Quality Education Project, Mimeographed Draft No. 2, May, 1965.

F. Kopstein relates general systems theory and system analysis in devising an evaluation procedure for measuring objectively the adequacy and efficiency of the educational programs of the public schools of the state of Pennsylvania. 'System' is defined as events taken over time among which there exist unidirectional, probabilistic relationships such that event p is necessary but not sufficient for even q to occur, although p implies q with a probability greater than zero. The properties--states, input, output, feedback, subsystems--are discussed within the framework of system analysis, so that specific quantitative measures can be associated with these properties in such a way that measures of adequacy and efficiency can be determined.

7. Maccia, Elizabeth Steiner, "An Educational Theory Model: Graph Theory," Cooperative Research Project No. 1632, Construction of Educational Theory Models, The Ohio State University Research Foundation, 1963, pp. 101-138.

" . . . graph theory [is shown to be] utilizable in formulating characterizations of relations of persons in groups within the schools." (p. 101) The results are not only

the educational theory model, but the tentative educational theory as well. Furthermore, some relevance and fruitfulness of the theory is indicated.

8. Maccia, Elizabeth Steiner, "An Educational Theory Model: Information Theory," Cooperative Research Project No. 1632, Construction of Educational Theory Models, The Ohio State University Research Foundation, 1963, pp. 298-334.

   Portions of information theory are presented and used as a model for constructing an educational theory in which the teaching-learning process becomes a problem solving or inquiry process. Studies which support and are suggested by the educational theory are cited.

9. Maccia, Elizabeth Steiner, "Instruction as Influence toward Rule-Governed Behavior," Theories of Instruction, ed. by James B. Macdonald and Robert R. Leeper, Association for Supervision and Curriculum Development, Washington, D.C., 1965, pp. 88-99.

   E. Maccia combines her work in items 7 and 8 and presents a scientific theory in which " . . . instruction is viewed as influence toward rule-governed behavior" (p. 91). The influence dimension of the theory is primarily concerned " . . . with structure variables which are descriptions of the internal behavior of the classroom group members" (p. 91). Digraph theory is used to represent influence structure and the relation of these structures to other variables is indicated. The teacher, via five possible motivational bases which establish influence relations, builds up the cognitive structures of the student. The analysis of the structure of any discipline, therefore, is a prerequisite for its being taught. The rule-governed behavior dimension of the theory views the student as a problem-solver. The solving of problems is accomplished through cognitive structures (rules) which permit selection from sets of alternatives (problems), and hence the use of selective information theory is apparent.

10. Maccia, George S., "An Educational Theory Model: General Systems Theory," Cooperative Research Project No. 1632, Construction of Educational Theory Models, The Ohio State University Research Foundation, 1963, pp. 139-172.

    Terms and propositions from general systems theory are organized into a theory model. The theory model is utilized then to set forth a tentative educational theory in which the school is characterized as a system with certain properties and actions. Studies which support and are suggested by the educational theory are cited.

11. Macdonald, James B. "Curriculum Theory: Problems and a Prospectus," Mimeographed copy of a paper read at the Professors of Curriculum Meeting, Miami Beach, Florida, April 3, 1964, 17 pp.

J. Macdonald uses concepts from general systems theory: system, input, output, feedback, adaptation, integration, tension channel, and goal achievement as a perspective for generating some hypotheses of curriculum theory. Three hypotheses are cited. One hypothesis is as follows: "That extensive curriculum change along lines associated with professional and/or behavioral input dimensions is dependent upon manipulation of impetus coming from a broad social context" (p. 16). The presentation in this paper is primarily an illustrative discussion of the possibilities for using general systems theory as an heuristic source for curriculum theorizing.

12. Miller, James G., "The Information Explosion: Implications for Teaching," Journal of the National Association of Women Deans and Counselors, Vol. 27, 1964, pp. 54-59.

Studies on information processing in living systems when there is an overload have suggested several types of adjustment processes. It is suggested that education become more oriented to teaching the student these methods of information processing. Although Miller simply applies the theory directly to educational practice, nevertheless a full development of the suggestion would result in an educational theory undergirding the practice. Consequently, the paper is cited in this annotated bibliography.

13. Novak, Joseph D., "An Approach to the Interpretation and Measurement of Problem Solving Ability, Science Education, Vol. 45, 1961, pp. 122-131.

"A theory of problem solving behavior based on an interpretation of the role of stored information and acquired information in selection of "courses of action" or behaviors has implications for the construction of a test to measure problem solving ability." (p. 130) This item is included because the usefulness of construing problem solving behavior as a selective information process is indicated, even though the main concern of the paper is the construction of the test.

14. Packer, C. Kyle, and Packer, Toni, "Cybernetics, Information Theory and the Educative Process," Teachers College Record, Vol. 61, 1959, pp. 134-142.

The relevance of the concepts of feedback, selective information, and coupling for education is discussed. " . . . in a system involving feedback . . . the pupil's performance is taken as part of the information on which the teacher continues to act, and some of this information coming back to the pupil, is the difference between the pupil's actual performance and the given pattern." (p. 137) "The set of possible messages is a different base of operation from the message. Clearly, then, the teacher's function includes knowing not merely the subject, or message, but the other possibilities - the set - from which this message is selected." (p. 139) " . . . the teacher and the student are linked in a system in which . . . reciprocal communication is of utmost importance." (p. 140)

15. Ryans, David G., "An Information-Systems Approach to Education," Systems Development Corporation, Santa Monica, California, TM-1495, 1963.

Ryans points out that education may be viewed as a general open system with inputs and outputs, and its subdivisions, e.g. the classroom, as subsystems. All systems exchange information either among elements or subsystems or with other systems. For Ryans, information is not a set of alternatives: " . . . it is best defined in terms of signs that have semantic and/or pragmatic referents . . ." (p. 6). The system concepts of steady state, cumulative modifiability, and equifinality are indicated as characteristics of educational information systems. A theory of instruction is devised from the general system-information theory context--one which emphasizes "(a) the interdependence and interrelatedness of conditions and operations influencing teaching-learning; (b) the information processing nature of what goes on when a teacher . . . reaches decisions about and programs instructional behavior (and what similarly goes on when a pupil receives [and assimilates] information from a teacher or instructional instrument . . .; and (c) the information exchange . . . nature of all instruction" (p. 11). The theory is presented as an information-flow paradigm, and the explication is with reference to this paradigm. A specific educational system constructed from the theory is described.

16. Ryans, David G., "An Information-System Approach to Theory of Instruction with Special Reference to the Teacher," System Development Corporation, Santa Monica, California, SP-1079, 1963.

Ryans summarizes general systems theory, selective information theory, a teacher characteristics study, and a theory of behavior whose unit of behavior is dyadic. These four bodies of knowledge provide the basis for an information-system theory of the instructional process. Ryans specifically rejects the definition of selective information for a "broader" one (see item 15). Ryans views the teacher as a system of three subsystems: external information inputs, internal information inputs and information processing capabilities, and teacher information processing. The components of the first two subsystems are defined topically, e.g. behavior-content, culture, general capabilities, etc. Although two of the topically defined components of the third subsystem are couched in information theoretic terms, e.g. input processing: sensing, filtering, etc., the role of selective information is never explicated. The system is presented as an information flow diagram, and this diagram is used to formulate general functional relations between the components. The general system concepts which are used in the theory are a) the concept of the teacher as a system of subsystems of interacting components, b) the concepts of input, output, and feedback of the system, subsystems, and components, and c) the assertion that the individual teacher is an open, self-organizing, self-regulating system. A similar theory is developed for the pupil and the situation complex. The learning process is then represented as an interaction of the teacher system, and the pupil system and the situation complex.

17. Ryans, David G., "A Model of Instruction Based on Information System Concepts." Theories of Instruction, ed. by James B. Macdonald and Robert R. Leeper, Association for Supervision and Curriculum Development, Washington, D.C., 1965, pp. 36-61.

This paper is a concise statement by Ryans of his theory of instruction which he presents in items 15 and 16. In addition several areas of educational research indicated by the theory are indicated.

18. Ryans, David G., "The Application of Programmed Instruction and Auto-Instructional Devices in Colleges and their Relation to a Theory of Instruction," System Development Corporation, Santa Monica, California, SP-1084/000/01, 1963.

"This statement is an attempt to look briefly at the purposes, essential characteristics, and potential utility of "programmed instruction" and, especially, to recommend that research and practice with respect to programmed instruction be viewed within a context provided by a theoretical model the author has chosen to label an "information system theory of teaching-learning."" (p. 1) A summary of this model (theory) is presented. For a more complete description of the theory, see items 15 and 16.

19. Thomas, J. Alan, "Administrative Rationality and the Productivity of School Systems," Midwest Administration Center, The University of Chicago, June 22, 1964, Mimeographed paper, 52 pp.

J. Thomas asserts that "the administrator plays a direct role in affecting the productivity of educational systems" (p. 2). He analyzes this assertion by defining 'system productivity' as a relationship between outputs and inputs. Specific outputs and inputs are cited, and three hypotheses relating these variables are presented: 1) "Short-term (performance-type) outputs are a function of levels of resource inputs; the characteristics of students as indexed by variables describing the home and community from which they come; the knowledge which is brought to bear on the solution of educational problems; and an error term" (p. 28), 2) "Intermediate outcomes (e.g. college-going, success in college, level of schooling completed) are functions of mean test scores; levels of resource input; characteristics of students; knowledge; and an error term" (p. 28), and 3) "Long-term outputs (e.g. Mean income N years after graduation) are functions of intermediate outputs (e.g. years of school completed); short term outputs (mean achievement in school); resource inputs; characteristics of students; knowledge; and an error term" (pp. 28-29).

20. Travers, Robert M. W., "On the Transmission of Information to Human Receivers," Theories of Instruction, ed. by James B. Macdonald and Robert R. Leeper, Association for Supervision and Curriculum Development, Washington, D.C., 1965, pp. 18-35.

Travers presents a summary of the research on human information processing. In most parts of the paper 'information' is taken synonomously with 'sensory input'. The relevance of this body of knowledge to education is indicated by

> references to educational practices which do not utilize the principles of information processing which Travers discussed. However, the framing of classroom situations in terms of informational constructs has implications for the construction of educational theory. For example, the teacher should be aware that in any sensory channel there is noise associated with informational input, and it is possible to code information. A restatement of a postulate of the progressive education movement in informational terms is relevant to a selective information context for education: " . . . given several sources of information from which to choose, the pupil would select those which provided information related to the satisfaction of his needs" (p. 30).

Using the SIGGS Theory as a Theory Model

General Discussion

Although what we take to be a theory model and to be its use have been presented in other writings (16), a short summary statement related to the use of the SIGGS Theory as a theory model for a theory of education is required, if one is to understand what we are about in this second section of this paper.

A theory model is a characterization used to develop yet another characterization. The characterization developed must be theoretical, since the model for is one for a theory and thus is called 'a theory model'. To be a theoretical characterization, a characterization must be set forth as propositions which are general and which are related in some systematic manner.

The characterization being used as the theory model is, in this case, also a theory. The theory model is a theory consisting of an incorporation of set theory (S) and information theory (I) and graph theory (G) into general systems theory (GS). Hence, it is called 'the SIGGS Theory', and when it is used as a theory model, 'the SIGGS Theory Model'.

The characterization which we are concerned to develop from the SIGGS Theory Model is a group of related general propositions about education. As implied in the first section of this paper, education is taken to be the teaching-learning process within the context of the school. This limitation in context is imposed in order that the proportion of the theoretical task can be reduced to a manageable size. Moveover, we are concerned with a theory of education which is a scientific one. That is to say, we are concerned to develop a group of related general propositions about the teaching-learning process within the context of the school which are hypotheses to be checked out through observation. Yet another point should be emphasized: we are not concerned to develop a praxiological theory of education, although such a theory could be scientific. In praxiological educational theorizing, the purpose is to develop a group of related hypotheses about educational practices with respect to selected outcomes of education. Our purpose, however, is non-praxiological although scientific. We are concerned to set forth hypotheses not about how some outcome or outcomes of education can be attained but rather about human behavior and other factors involved in education irrespective of selected outcomes of education. Finally, it should be patent that we are not concerned to do educational theorizing that is philosophic in type. We are not concerned to set forth a group of related hypotheses about desirable outcomes of education.

In developing the non-praxiological scientific theory of education from the SIGGS Theory Model, the method is neither reductive nor deductive but instead retroductive. The theory of education is neither equivalent to nor inferrable from the SIGGS Theory, rather the method is one in which content beyond what is in the SIGGS Theory must be introduced. This retroductive process will be illustrated as the outlines of developing an educational theory from the SIGGS Theory are sketched in the remaining portion of this second section of this paper. The sketch will outline the marking off of a school as a system, the setting forth of variables of a school as a system, and the setting forth of hypotheses which relate the variables of a school as a system.

Marking Off a School as a System

If one is to mark off a system, not only must the requirements of the definition of 'system' be met but also meaning must be introduced to mark off one kind of system from another. The latter requirement, the introduction of meaning, substantiates that the use of the SIGGS Theory in developing other theory is not reductive or deductive but is retroductive.

The requirements of the definition of 'system' are as follows:

1. since the system must be a group of components which is a set, the components constituting the group must be well-defined;
2. there must be at least two distinct components;
3. the group must have selective information, and the definition of 'selective information' requires that

3.1. there must be a set of categories (being a set requires that the elements which are categories must be well-defined), and

3.2. there must be a probability of occurrence of the components of the group at each category;

4. since the group must have a set of affect relations defined upon it, the affect relations constituting the set must be well-defined; and

5. there must be at least one affect relation in the set, and the definition of 'affect relation' requires that

5.1. there must be a binary relation between components of the group which is a semi-path.

The marking off of a school as a system in terms of the above requirements now will be outlined. Since there is a requirement of introduction of meaning, another marking off of a system, an atom as a system, will be introduced to indicate the difference in meaning related to different kinds of systems. In both cases, the atom and the school, the requirement of the introduction of meaning will accompany the requirements of the definition of 'system'.

In an atom, the components are particles. There are many more kinds of atomic particles than the usually referred to triad (proton, neutron, and electron). Also there are more than one of a kind in most atoms. The above is not an adequate delineation, and hence the group is not well-defined. Any of a number of recent works summarizing the state of knowledge about atoms, however, would point up that the attempt to secure a well-defined group of particles has progressed and is continuing

to progress. In a school, the components are persons and things. There are many more kinds of persons than the usually referred to dyad (teacher and student), and there are many more kinds of things than the usually referred to monad (books). There are auxiliary persons, such as administrators and counselors, and there are other things, such as teaching machines among the numerous audio-visual devices. Also there are more than one of a kind in most schools. Most schools are crowded with students. The above is not an adequate delineation, and hence the group is not well-defined. A recent work which summarizes the state of knowledge about schools (17), however, does not point up much progress in setting forth a well-defined group which is a school. We hope to secure some progress as our work continues.

Even hydrogen, the most simple of the atoms, has at least two particles. The second requirement of the definition of 'system', consequently, is met, just as a school would meet it. Although the requirement in regard to a school usually is thought of in terms of the necessity of at least two distinct persons, a teacher and a student, the contemporary emphasis upon self-instruction would demand also at least two distinct components. Self-instruction requires at least one thing as well as a student.

In an atom, the location of a particle is not certain but is probable. There are categories (quantum levels), which do meet the requirements of being well-defined, with probabilities of occurrence of the particles at each quantum level. Clearly an atom meets the third requirement of its being a system, i.e. selective information.

To illustrate how a school would meet the requirement of selective information on the group of persons and things, consider that one of the things of a school is money. The location of money in a school (budget distribution) is not certain but probable. There are categories (types of budget demands within a school), which could meet the requirement of being well-defined, and to which probabilities of occurrence of the money with respect to demands could be assigned. Since other examples of selective information readily come to mind, such as distribution of students in classes and distribution of content in curricular materials, obviously there are more than one set of categories. A theory of education to be complete must delimit all the selective information on the group which is the school. This delimitation is a hope in regard to our continuing work.

Finally, to establish both an atom and a school as a system, the requirements with respect to affect relations (the fourth and fifth requirements) must be met. Our literature search (18) did not reveal that the atom was being considered in terms of graph theory as it relates to general systems theory. The atom, nevertheless, might be viewed as a group of particles which are point charges. The point charges might be related in a binary manner so that there would be a sequence of connections from one point charge to another which could be traced either by following (directed path) or not following the direction of the connections. In either case, the path is a semi-path. The requirement for an affect relation would be met, and this affect relation could be seen as an electro-magnetic field. In a school, an

obvious example of an affect relation is an instructing relation between teachers and students and between students. An instructing relation can be considered a binary one with a sequence of connections which is a semi-path. (19) Since other examples of affect relations of a school quickly can be cited, such as a decision-making relation and an allocating relation, undoubtedly the set of affect relations defined upon the group which is a school consists of more than one. To meet the fourth requirement, thus, necessitates the delineation of all of the affect relations. This delineation too is a hope which accompanies our continuing work.

Variables of a School as a System

A school as a system has properties which are variables. To state the matter in terms of what we take a property to be, a school has conditions defined upon it and these conditions can take on different values at different times. To select a very simple property of a school, sizeness, as an illustration: a school has size, i.e., a school has a certain number of persons and things which number can vary from two to a larger finite number. Sizeness of a school, therefore, is a variable.

The variables of a school can be sorted out in terms of whether the conditions are directly on the group or on the persons and things of the group or on the selective information which the group has or on the affect relations defined on the group or on any combination thereof. This sort would not be complete, for the selective information outside of a school and the introduction of time as it relates to such selective

information as well as to a school's conditions also are conditions which may be defined on a school. These conditions with the conditions stated above permit yet other combinations. Other properties or variables of a school, therefore, result.

The group of persons and things, including other schools, which are not the school taken as the system is the negasystem, i.e., the complement of the group of the school. (20) The negasystem of a school, at present, is taken as being of the earth, although the universe of discourse merits enlarging if societal invasion into or from outer space should become a reality. A property of a school defined in terms of the selective information on its negasystem would be environmentalness or toputness. Whatever in a school's negasystem has selective information becomes the environment or toput of that school. For example, a probability distribution of persons with respect to competency as teachers, if available to a school for selection, provides a school with toputness from which it can select teachers. Introducing time, the environment of a school changes. A school has the property of environmental changeness. The probability distribution of persons with respect to competency as teachers which is available to a school for selection, which is selective information of the negasystem, changes; the toputness from which a school can select its teachers changes.

Before discussing time as it relates to a school's conditions and resultant school properties, notice should be taken of the phrase, 'if available to a school for selection', in the above discussion of toputness. The phrase indicates the relational nature of selective information. There must be a selecting system, if there is to be a

negasystem which has selective information. Moreover, there must be a selecting negasystem, if there is to be a system which has selective information. Selective information must be a probability distribution with respect to categories, but it also must be taken as alternatives from which a selection can be made. This aspect of selective information was not made explicit, when we discussed the marking off of an atom and a school as systems. Clearly, the probability distribution of particles of an atom at quantum levels offers alternatives from which another atom (negasystem with respect to the atom taken as the system) can select. The example of selective information of a school which was set forth is not as patent. The probability distribution of the budget of a school at categories of demand does not seem to offer alternatives from which the negasystem of that school can select. The seeming is correct, for what is being considered is selective information of a part of the group which is a school in relation to another part of that same group which can select (the administrating part). The administrating part, thus, is the negasystem which can select from the part of the school which is the system which has the selective information. This example introduces the property of a school, subsystemness. Persons and things within the school can be systems. Finally, this example permits emphasis upon the shift of perspective possible in which what is taken to be a negasystem with respect to certain selective information may be viewed as a system with respect to other selective information. The administrating unit with respect to other selective information, e.g. policies, could offer alternatives for selection and also meet the other requirements for being a system. The administrating unit then becomes a system, a subsystem, within a school.

Turning now to a discussion of time as it relates to a school's conditions and the illustration of resultant properties of a school, a simple beginning would be stableness. A school can have the property of stableness with respect to one or more conditions, if there is no change in these conditions. An example would be stability of the sizeness of a school. The number of persons and things in a school would have to remain constant through time, if a school is to have the property of stableness with respect to sizeness. The number, however, might increase or decrease through time, and thus a school would have either the property of size growthness or size degenerationness. A more complex property of a school, equifinalness, depends upon a consideration of the state of a school. A given school at a given time has conditions; it has a state. The states of a school could be related in such a way that a state is derivable from more than one state. If this kind of derivation holds, then a school has equifinalness. That this property could be one of a school seems to follow from the fact that two schools having different developmental patterns, Harvard University (a private institution) and University of Michigan (a public institution), nevertheless reach the same state.

Up to this point in our discussion of variables of a school as a system, the following kinds of properties have been exemplified: a property directly on the school group, a property on the persons and things of the school group, a property resulting from selective information on the negasystem of a school, a property resulting from selective information on the negasystem of a school as it relates to time, and

four properties resulting from conditions of a school as they relate to time. The properties were respectively: sizeness, subsystemness, environmentalness or toputness, environmental changeness, stableness, size growthness, size degenerationness, and equifinalness. To complete this discussion, the following kinds of properties have yet to be exemplified: a property on the selective information on the school group, a property on the affect relations defined on the school group, and finally a combinatory property.

Feedoutness is a property on the selective information on a school group. Feedoutness is the system selective information that is transmitted into the negasystem, it is the commonality between the selective information on a school group available to the negasystem for selection (fromputness, another property of a school) and the selective information on a school group selected by the negasystem (outputness, another property of a school). For example, a senior high school has students who make themselves available for selection by other schools which are schools of higher learning. Note that the negasystem may be restricted to a part of the persons and things outside of a school. The basis for restriction is the establishment of a complement that is within the universe of discourse. In this case schools of higher learning would be the complement, since it is to such schools that certain students of the group of students in a senior high school are making themselves available. There are categories of achievement, which could meet the requirements of being well-defined, and to which probabilities of occurrence of these students with respect to these

categories could be assigned. There would be selective information, alternatives from which the schools of higher learning could select. After the selection, there would be a probability distribution of the students selected. If there is complete correspondence between the two probability distributions, then there is complete feedoutness of these persons of the system into the delimited negasystem, the selective information available for selection (fromput) is equal to the selective information selected (output).

Disconnectedness is a property on the affect relations defined on a school. With respect to one or more kinds of affect relations defined on a school (instructing, decision-making, allocating, etc.) there are some persons or things which may not be connected. Not being connected is the property of independentness. An example of disconnectedness would be students independent of (isolated from) instruction. Such students neither learn nor do they influence anyone else to learn. Another example, would be isolates of a school staff with respect to the allocation of certain resources, such as salary.

To complete this discussion, comprehensive growthness will be considered in order to exemplify a combinatory property. A school would have the property of comprehensive growthness, if its comprehensiveness is increasing. The comprehensiveness of a school includes its sizeness, its complexness, and its selective informationness. Sizeness has been considered already. Complexness refers to the number of affect relations defined upon a school, while selective informationness refers to the amount of selective information on the group of a school. The emergence of the comprehensive high school and the multi-university are excellent examples of comprehensive growthness.

Hypotheses About a School as a System

To complete the sketch which outlines the development of an educational theory from the SIGGS Theory, some illustrative hypotheses which relate variables of a school as a system will be set forth.

One hypothesis which relates the variables of size growthness and independentness would be as follows:

> As the number of persons and things in a school increases, the number of persons and things in that school which are not connected increases.

For example, as the number of students in a class increases, the number of students who are isolates with respect to instruction increases. A more dramatic example would be the fractionation of the university into the multi-university under the impact of the large numbers of students, the explosion of knowledge, and other increases. This more dramatic example indicates that size is related to the number of isolated subsystems. The hypothesis would relate the variables of size growthness, subsystemness, and independentness.

> As the number of persons and things in a school increases then the number of persons and things which are subsystems in that school and which are not connected increases.

Turning to information theoretic variables, a relationship between the variables, inputness and filtrationness, will be set forth. Filtrationness is a variable which was not discussed earlier. Filtrationness is another property of a school defined upon the selective information of the negasystem of that school; it is some of the toput

which is not selected by a school. To illustrate, some of the prospective faculty available to a school might not be selected. If this happens, then the school has the property of filtrationness. Filtration could occur with respect to things also; not all the knowledge available to a school need be included in its curriculum. The relationship between the variables, inputness and filtrationness, is stated in the following hypothesis:

As the filtrationness increases, the inputness decreases. Diagram 1 represents the simplest case of this hypothesis in which toputness (environmentalness) is taken as constant.

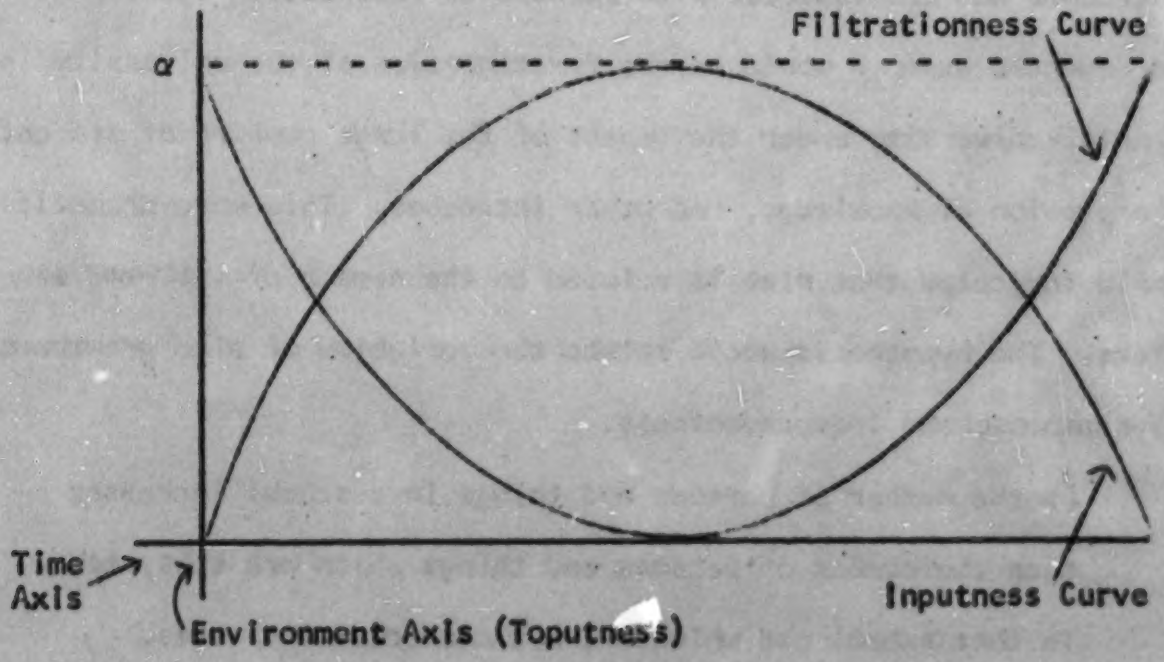

Diagram 1

To explain the hypothesis in terms of the diagram: if α is the upper limit of the alternatives with respect to faculty for a school, then as rejection of this selective information by a school (filtrationness) increases, selection of this selective information (inputness) decreases.

In other words, the selective information with respect to prospective faculty on the negasystem of a school must equal the filtered portion plus the inputed portion.

Diagram 1 could be utilized also to exemplify the relationship between spillageness and feedinness. Spillageness is the negasystem selective information which is available to a system but which is not transmitted into the system (21), while feedinness is that which is transmitted. If α is the upper limit of transmitted selective information, then as spillageness increases, feedinness decreases.

Some other hypotheses involving graph theoretic variables, besides the first hypothesis which was stated, are as follows:

As strongness decreases, vulnerableness increases.

As compactness decreases, hierarchically orderness decreases.

Since these hypotheses introduce variables which were not discussed previously, their meaning must be stated in order that the hypotheses may be understood.

Strongness is a property on one or more affect relations of a school in which one or more of these relations are such that each person and thing affects and is affected by every other person and thing but not each person and thing directly affects and is directly affected by every other person and thing. Consider a group of curricular responses as a subsystem of a school, and thus as an instructing system. If the group of responses have the property of strongness, one or more of the kinds of connections between the responses will be such that each

response affects and is affected by every other response but not each response directly affects and is affected by every other response. Vulnerableness is a property also on the affect relations of a school in which one or more of the affect relations are such that there are some connections which when removed produce disconnectedness. Considering again a group of curricular responses as an instructing system, if they have the property of vulnerableness, then one or more of the kinds of connections between the responses will be such that there are some connections which when removed produce disconnectedness. The hypothesis relating strongness and vulnerableness must be apparent as well as its illustration in terms of a group of responses as an instructing system. The illustration points to interrelatedness of responses, as in programmed learning, as a deterrent to forgetting.

Compactness is the closeness of connections between persons and things in a school, while hierarchically orderness is one or more levels of subordinateness of persons and things with respect to one or more kinds of affect relations defined on a school. An example will be given in the context of administration within a school. Taking the administrating portion of a school as a subsystem and hence as a system, if it has the property of compactness, there is closeness of connections between administrators, and if it has the property of hierarchically orderness, there is one or more levels of administrators with respect to decision-making and other affect relations defined on the administrating unit. Obviously, compactness and hierarchically orderness are inversely related.

Summary

The purpose of this paper was twofold: to describe the usage of set theory, information theory, graph theory, and general systems theory in the construction of theory in education, and to show how one can extend the usage through our research which has produced the SIGGS Theory.

The first purpose was carried out through the discussion and presentation of an annotated bibliography. The conclusion was that the usage is not in a very advanced stage of development.

The second purpose was carried out through some illustrative moves in the construction of scientific educational theory by means of SIGGS Theory as a theory model. The illustrative moves included marking off a school as a system, and setting forth variables of a school as a system and scientific hypotheses relating the variables of a school as a system. A less probable conclusion as to extension of usage is the hope of our future work.

FOOTNOTES

(1) The first series of papers consists of two: Occasional Paper 65-179, "An Annotated Bibliography: Graph Theory as It Relates to General Systems Theory" and Occasional Paper 65-181, "An Annotated Bibliography: Information Theory as It Relates to General Systems Theory". The intent of this series is to present the literature relevant to the development of an educational theory model from general systems theory, graph theory, and information theory.

(2) The second series of papers consists of three: Occasional Paper 65-182, "Graph Theory as It Relates to General Systems Theory," Occasional Paper 65-183, "Information Theory as It Relates to General Systems Theory," and Occasional Paper 65-184, "Set Theory as It Relates to General Systems Theory". The intent of this series is to present theories as they relate to one another in the development of an educational theory model. Set Theory was a fourth model introduced, since it emerged as such in the ongoing work of the project. It was unnecessary to introduce into the first series an annotated bibliography with regard to set theory as it relates to general systems theory, since only two such relatings were discovered and are cited in Occasional Paper 65-184.

(3) The third series of papers consists of these: Occasional Paper 65-185, "An Integration of Set Theory, Information Theory, and Graph Theory with General Systems Theory: Variables", Occasional Paper 65-186, "An Integration of Set Theory, Information Theory, and Graph Theory with General Systems Theory: Propositions", and this paper. The intent of this series is to present the educational theory model.

(4) The fourth series of papers will consist of three: "The SIGGS Educational Theory: Variables", "The SIGGS Educational Theory: Propositions", and "The SIGGS Educational Theory: Its Adequacy". The intent of this series will be to present the educational theory and its checking in terms of relevant data. All of these papers, with the exception of the fourth series not yet completed, are available from the Educational Theory Center, The Ohio State University.

(5) This project was extended by the U. S. Office of Education in order to permit the introduction of the fourth model, i.e., set theory.

(6) L. A. Cook, "An Experimental Socio-graphic Study of a Stratified 10th Grade Class," American Sociological Review, Vol. 10, 1945, pp. 250-261.

(7) W. W. Lewis and John M. Newell, "Analysis of Classroom Interaction through Communication Behaviors," Journal of Experimental Education, Vol. 30, 1962, p. 321.

(8) O. J. Harvey, David E. Hunt, and Harold M. Schroder, Conceptual Systems and Personality Organization, New York: John Wiley and Sons, Inc., 1961.

(9) Bruce R. Joyce, "A Summary of Exploratory Research in Education Utilizing Conceptual Systems Theory," Presented to the American Educational Research Association Annual Meeting, February, 1964, as part of a symposium, "The Relevance of Conceptual Systems Theory to Educational Research," mimeographed manuscript, 25 pp.

(10) Paul R. Hanna and Richard E. Hodges, "Spelling and Communications Theory: A Model and an Annotated Bibliography," Elementary English, Vol. 40, 1963, pp. 483-505.

(11) T. B. Greenfield, "Administration and Systems Analysis," The Canadian Administrator, Vol. 3, No. 7, 1964, pp. 25-30.

(12) In a series of three articles in Systematics (Vol. 2, No. 1, 1964 pp. 1-46, Vol. 2, No. 3, 1964, pp. 177-213, and Vol. 2, No. 4, 1965, pp. 298-322), Anthony M. Hodgson presents a theory of creative problem solving in groups based upon a combination of general systems theory and graph theory. These three papers are cited here, since, although Hodgson constructs no educational theory, he notes the relevance of his theory for education.

(13) Robert L. Granger, Educational Administration and Information Process, Department of Educational Administration, College of Education, University of Minnesota, 1965.

(14) Ibid., p. 6.

(15) See page 6 of Item 15.

(16) See the following writings: Section I, "Metatheory: Retroduction, Models, and Educational Theorizing" and Section II, "Metatheoretical Background: Models in the Ongoing Endeavor of Educational Theorizing," in Construction of Educational Theory Models by E. S. Maccia, G. S. Maccia, and R. E. Jewett, Cooperative Research Project No. 1632, The Ohio State University Research Foundation, 1963, pp. 1-100; "Educational Theory Models: A Possible Way to Stretch the Bounds of Teacher Education," by E. S. Maccia in Analysis and Projection of Research in Teacher Education by F. R. Cyphert and E. Spaights, Cooperative Research Project No. F-015, The Ohio State University Research Foundation, 1963, pp. 174-196; "Retroduction: A Way of Inquiring Through Models," Memorias Del XIII Congreso Internacional De Filosofia, Volumen V, Communicaciones Libres, 1964, pp. 545-562; and "The Model in Theorizing and Research," Presented at the International Reading Association, 1965, and to be published by that Association.

(17) See the Handbook of Research on Teaching, edited by N. L. Gage, Chicago: Rand McNally & Co., 1963.

(18) See Occasional Paper 65-179, "An Annotated Bibliography: Graph Theory As It Relates to General Systems Theory," one of the papers of this project.

(19) See item 7 of the annotated bibliography in this paper.

(20) See Occasional Paper 65-185, "An Integration of Set Theory, Information Theory, and Graph Theory with General Systems Theory: Variables," one of the papers of this project; and note that the definition of 9 on p. 9 is in error: the negasystem is taken as the complement of the system, but it should be taken as the complement with respect to the universe of discourse of the group of the system.

(21) See paper cited in footnote 20; and note that the definition of 12-14.2 is incorrect. The correct definition is:

$$SL =_{Df} \exists T'(T' = \max T(TP,IP) - T(TP,IP))$$